Beyond Standard Model searches in ultraperipheral heavy-ion collisions with ATLAS

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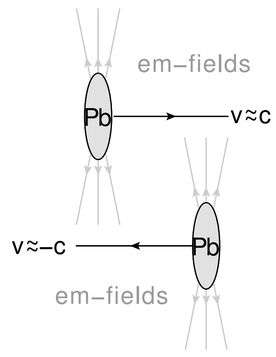
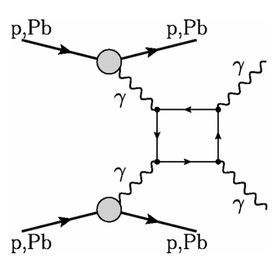
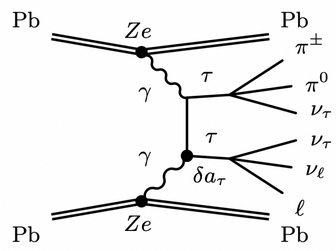
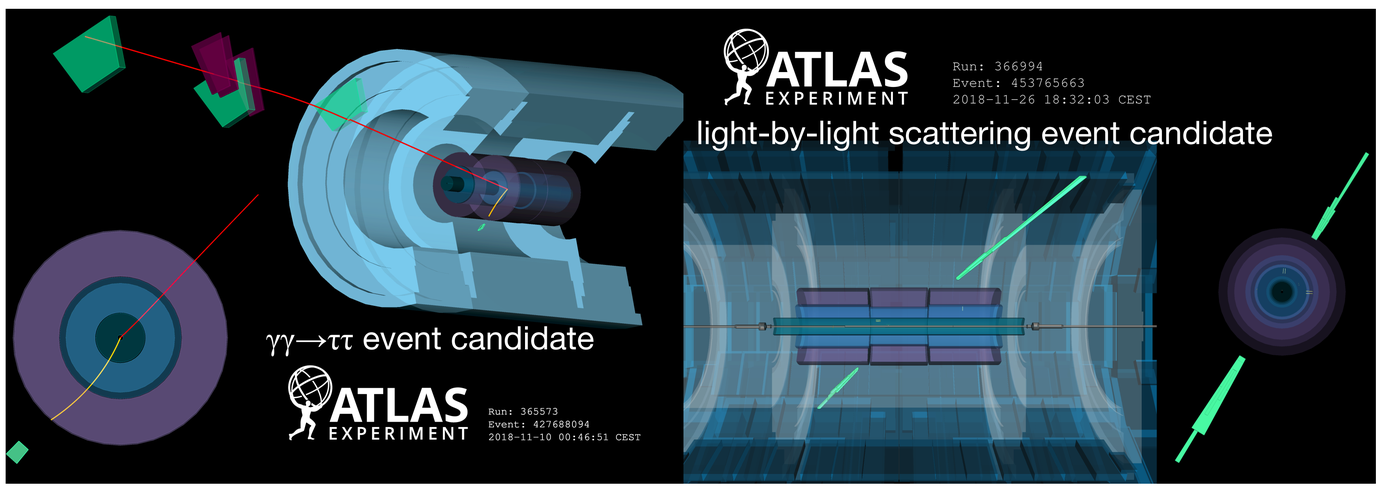
Ultraperipheral heavy-ion collisions

- **Photon-photon interactions** can be observed in **ultraperipheral heavy-ion collisions** at the LHC due to large EM fields associated with relativistic ions (cross-sections scale with ~ Z^4)
  - **Advantages:** low hadronic pileup, possibility of lower trigger thresholds
- EM field is treated as a beam of **quasi-real photons** with small virtuality (equivalent photon approximation)
- The EM interactions are dominant for impact parameters larger than $2R_A$
- Incoming **photon fluxes** are studied in detail with exclusive dilepton production measurements [1,2]
- Possibility to study **rare processes:**
  - light-by-light (LbyL) scattering [3-5]
  - Exclusive ditau production in semi-/fully-leptonic decay channels [6]
  - Exotic hadron production search proposed [7]



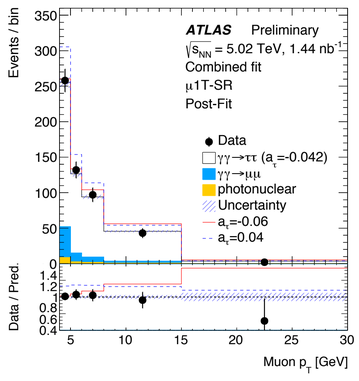


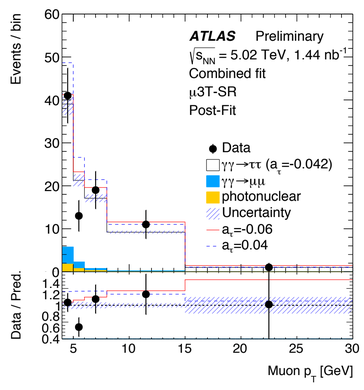


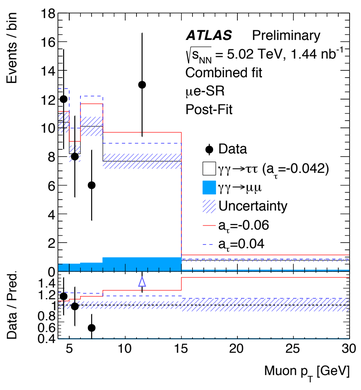


a_τ - measurement strategy

- **Signal** τ-leptons are **low-energetic**, typically with p_T < 10 GeV
- No standard ATLAS identification of τ-leptons is used,
  - Instead events classified based on the charged τ-lepton decay products
- **Three signal categories:** μ + 1 track, μ + 3 tracks, μ + e
- Single muon trigger used to record signal events with muon p_T > 4 GeV
- **Exclusivity requirements:** veto on additional tracks, low-p_T clusters, and forward neutron activity (using 0n0n configuration based on ZDC signal)
- Main **background contributions** from dimuon production and diffractive photonuclear interactions
- Dimuon **control region** (γγ → μμ events) used to **reduce systematic uncertainty** from the photon flux

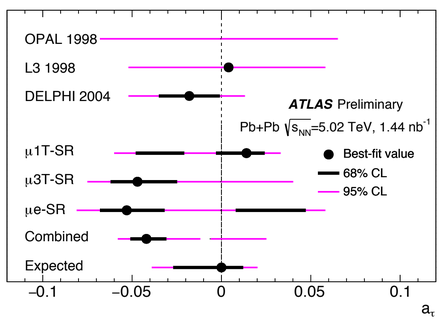


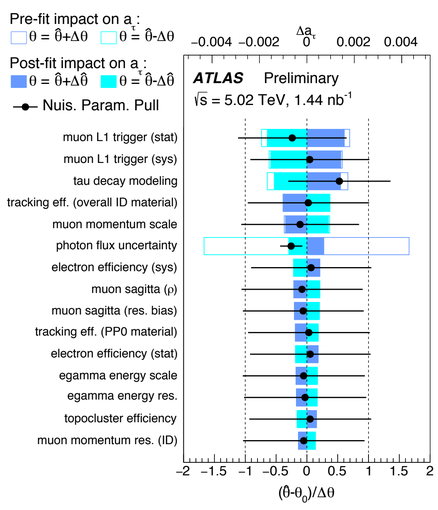




a_τ - results

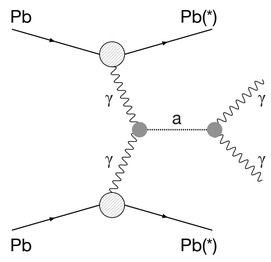
- The a_τ value is extracted using a **profile likelihood fit** using the muon p_T distribution
- **Simultaneous fit** combining all signal regions and dimuon control region
- Calculations are based on the same parameterization as was used in previous LEP measurements
- Approximately 80 **nuisance parameters** (statistical and systematic uncertainties) are included in the fit
- Many of them correlated between signal and control region
- The **best fit value** is a_τ = –0.042, with the corresponding **95% CL interval** being (–0.058, –0.012) ∪ (–0.006, 0.025)
- The result is largely limited by statistics
- Constraints similar to DELPHI [11]





BSM searches

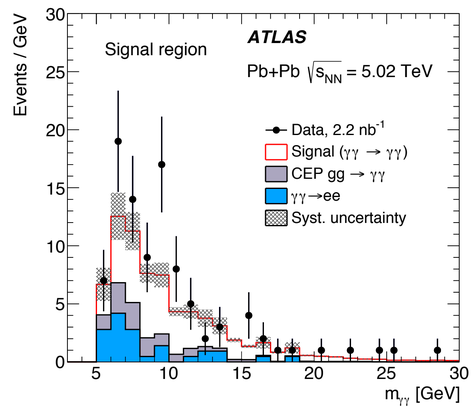
- Axion-like particles (ALP) are **hypothesized** (pseudo-)scalar **particles** that appear in many theories with a spontaneously broken global symmetry
- ALPs may **decay to two photons** [8]
- Presence of ALP could be observed as an enhancement in the diphoton mass distribution



- It is possible to set constraints on **anomalous magnetic moment** of the τ-lepton $a_\tau = (g-2)_\tau/2$ using γγ → ττ events [9,10]
- Some **BSM models** predict modifications of a_τ, e.g. lepton compositeness, supersymmetry ($\delta a_\tau \sim m^2_\tau/M^2_S$) or TeV-scale leptoquarks

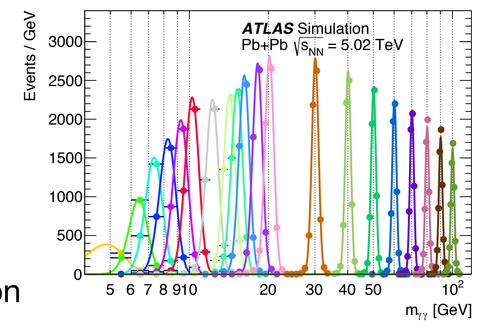
ALPs - γγ → γγ event selection

- The signature is: **two low-E_T, back-to-back photons** without any additional activity in the detector
- Dedicated **diphoton trigger** was developed
- New photon **identification** procedure based on **neural network** was developed and optimized for low-E_T photons
- **Fiducial selection:** two photons each with transverse energy E_T^γ > 2.5 GeV, pseudorapidity $|\eta_\gamma|$ < 2.37, diphoton invariant mass $m_{\gamma\gamma}$ > 5 GeV, diphoton transverse momentum below 1 GeV
- **Background suppression** by requiring no additional tracks and diphoton acoplanarity (=1-|Δφ|/π) below 0.01
- **Background** sources from γγ → ee and Central Exclusive production (CEP) are estimated using **data-driven** techniques



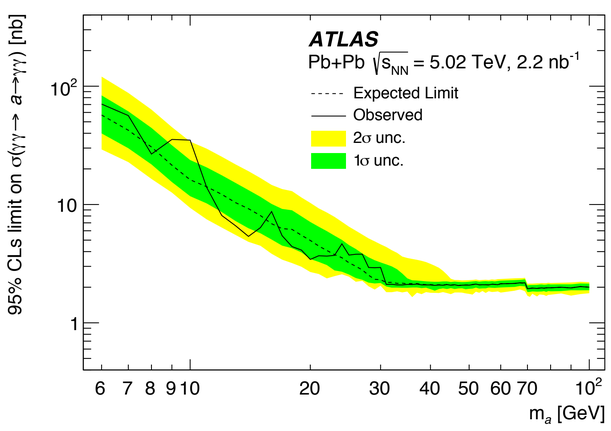
ALPs - methodology

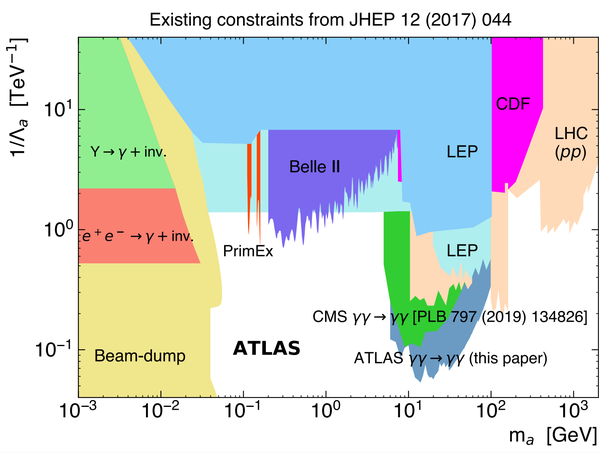
- Events for the ALP signal were generated using Starlight MC generator for various ALP masses (m_a) ranging between 5 and 100 GeV
- The **search** is performed using $m_{\gamma\gamma}$ distribution
- Simulated LbyL events are normalized to the data yield, after subtracting γγ → e^+e^- and CEP gg → γγ contributions and excluding the mass search region



ALPs - results

- ALP contribution is fitted individually for every mass bin using a maximum-likelihood fit
- **No significant deviation** from the Standard Model **background-only hypothesis** is observed
- The result is used to estimate the upper limit on the **ALP cross-section** and **ALP coupling** $1/\Lambda_a$ at 95% confidence level
- The obtained **exclusion limits** are the **strongest so far** for the mass range of 6 < m_a < 100 GeV





References: [1] Phys. Rev. C 104 (2021) 024906 [2] ATLAS-CONF-2022-025 [3] Nature Physics 13 (2017) 852
[4] Phys. Rev. Lett. 123 (2019) 052001 [5] JHEP 03 (2021) 243 [6] CERN-EP-2022-079
[7] Phys. Rev. D 104 (2021) 114029 [8] Phys. Rev. Lett. 118 (2017) 171801
[9] PRD 102 (2020) 113008 [10] PLB 809 (2020) 135682 [11] EPJ C 35 (2004) 159

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